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MEMORANDUM

Subject: Progress Report 015–
Chaotic LIDAR for Naval Applications: FY14 Q3 Progress Report (4/1/2014– 6/30/2014)

This document provides a progress report on the project "Chaotic LIDAR for Naval Applications" covering the period of 4/1/2014–6/30/2014.

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FY14 Q3 Progress Report: Chaotic LIDAR for Naval Applications

This document contains a **Progress Summary for FY14 Q3.**

Progress Summary for FY14 Q3

The use of chaotic lidar for underwater system experiments progressed in this quarter. Experiments were set up for ranging using the chaotic system. Channel identification experiments continued, using a high speed receiver and adaptive signal processing.

The chaotic lidar project was presented at the Defense, Sensing, and Security conference in Baltimore, MD on 07 May, with a talk entitled "Chaotic Lidar for Underwater Channel Identification". The slides from this presentation are attached.

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Chaotic Lidar for Underwater Channel Identification

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SPIE DSS 2014

Ocean Sensing and Monitoring

07 May 14

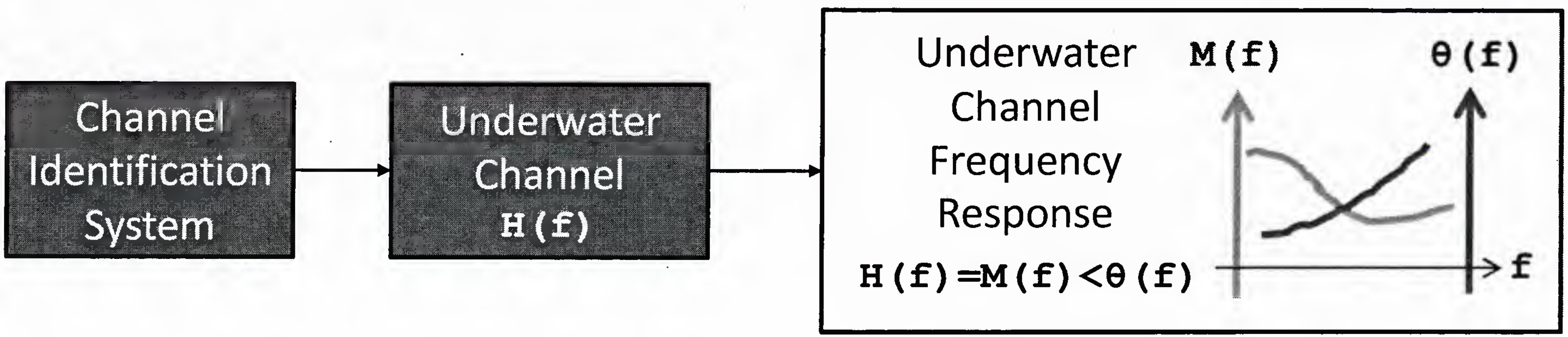
Outline

- Introduction
- Channel Identification
- Chaotic Lidar
- Preliminary Results
- Status and Future Work
- Conclusion

Goal: Channel Identification

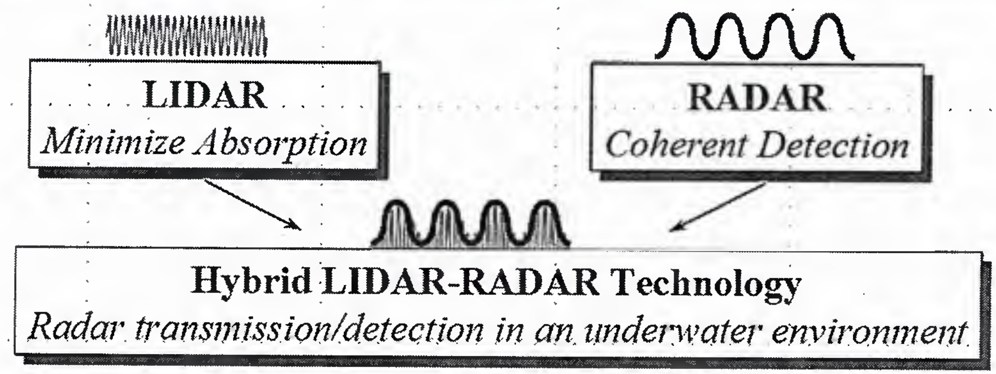
- Context
  - Intensity-modulated optical system operating in water (sensor, communications, ranging, imaging, mapping)

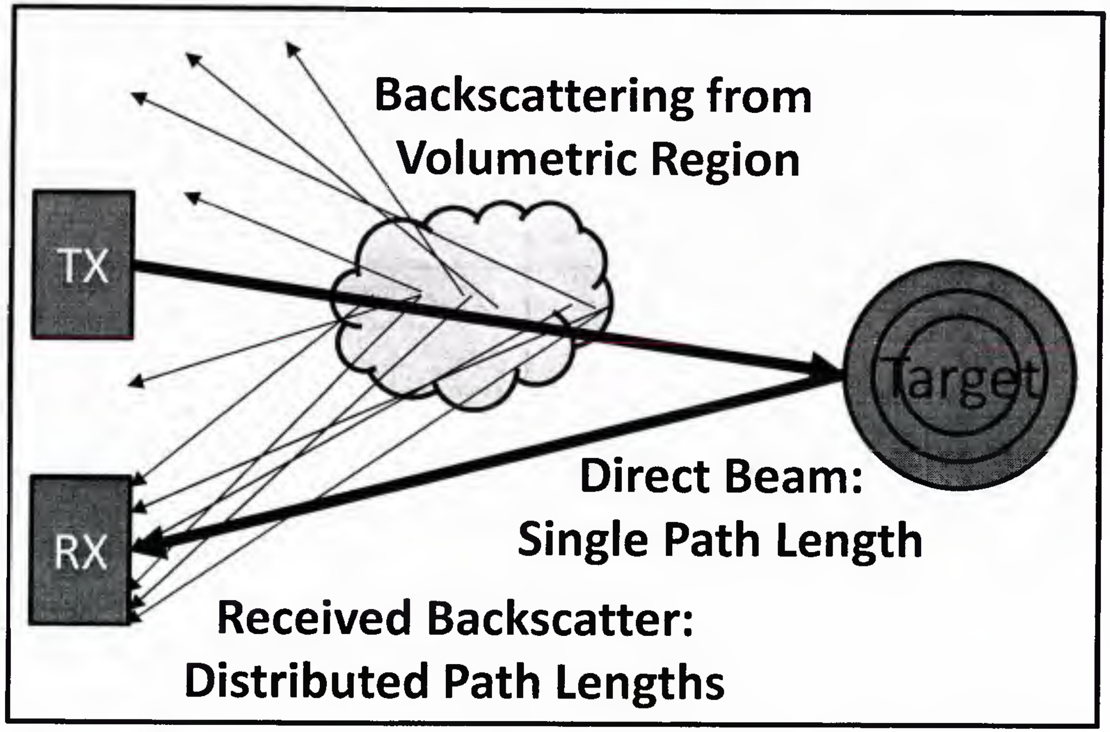
- Problem statement
  - Measure variation in system response as a function of frequency of intensity modulation
  - i.e., transfer function H(f) of the water



Motivation: Hybrid Lidar-Radar

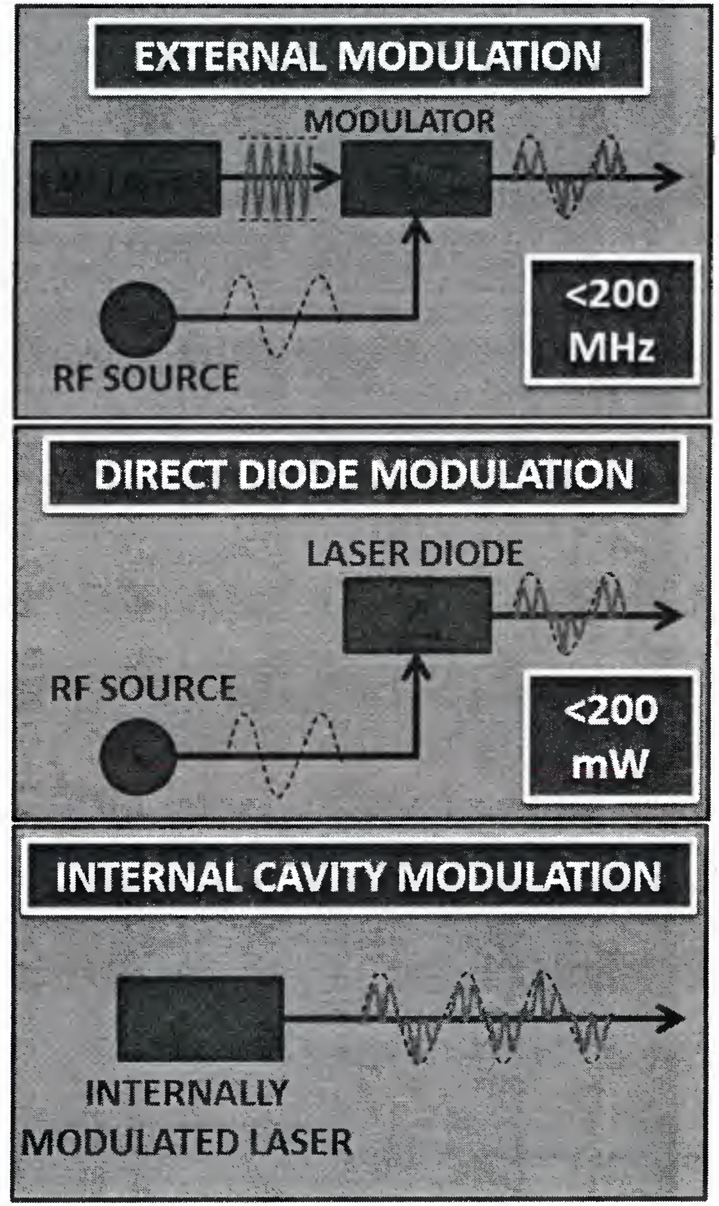
- Modulate optical carrier with radar signals
- Modulation discrimination against scattered light
  - Scattered light decorrelates as phase randomized
  - Decorrelation increases exponentially with frequency
  - Electrical discrimination improves performance
- Continuous monitoring of modulation response
  - Decorrelation effect changes with water conditions
  - Would like to explore frequency spectrum to 1 GHz





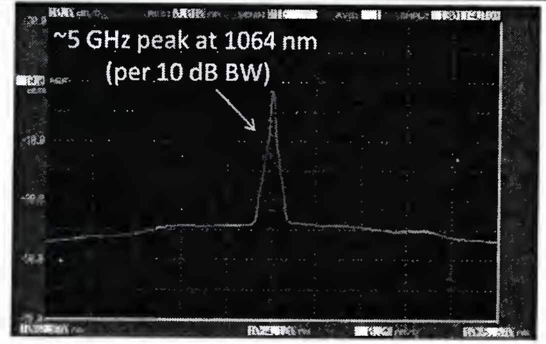
Challenges: High Frequency, High Power Lidar Systems

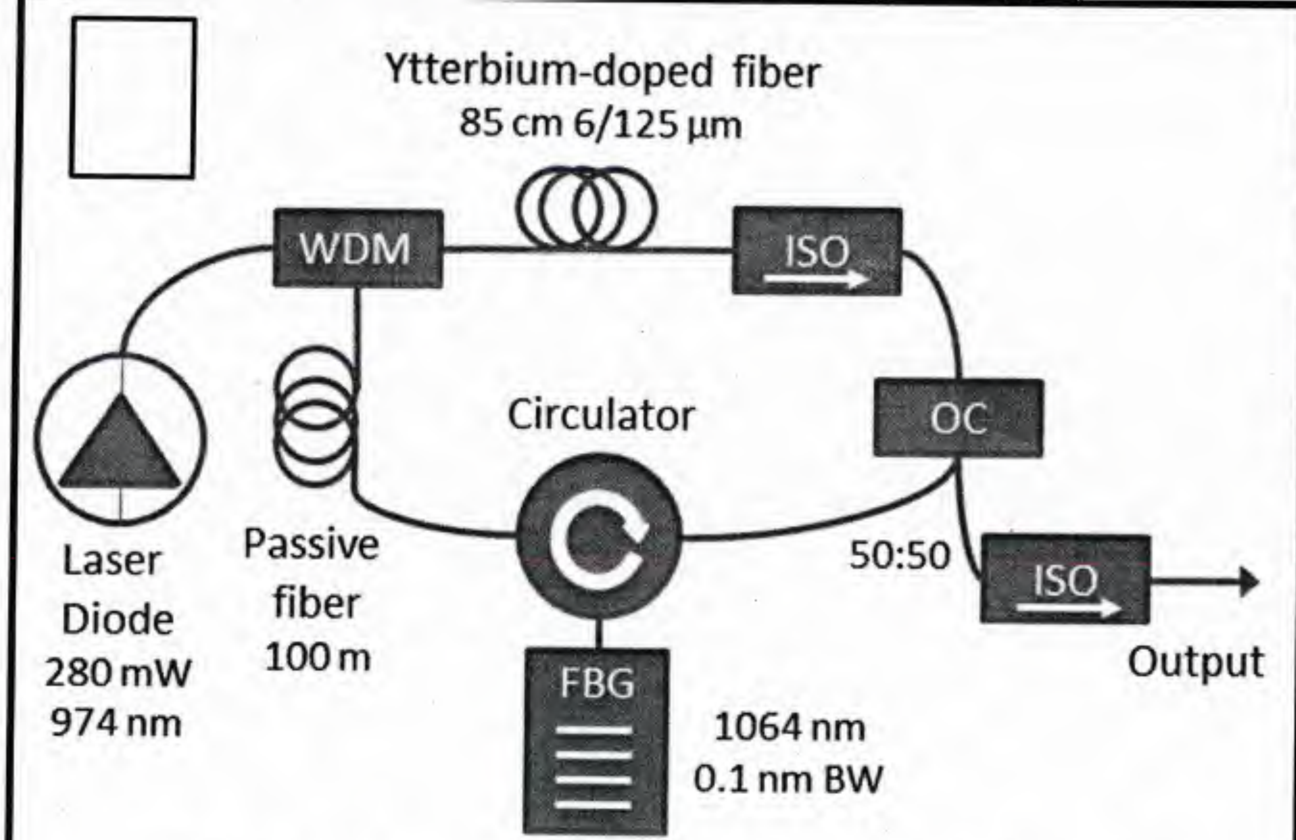
- Technology challenge for channel ID: GHz modulation with W power
- Systems to date
  - Bulk CW lasers with external modulators
  - Diodes with direct current modulation
  - Mode-locked pulsed lasers
  - Fiber lasers with high speed modulator
- Proposed: Internally modulated fiber laser
  - No modulator subsystem
  - Fiber laser allows high frequency
  - Fiber amplifiers allow high power
  - Frequency doubler for NIR → green



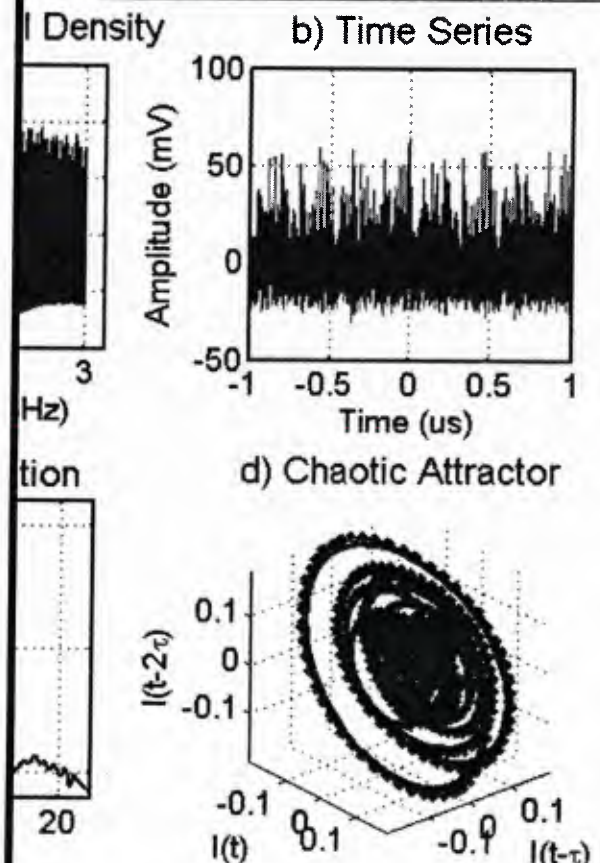
Internally Modulated Fiber Laser

- Chaotic ytterbium-doped fiber laser
- Uses ultralong cavity (>100 m) to encourage simultaneous, incoherent lasing of many chaotically competing resonant modes





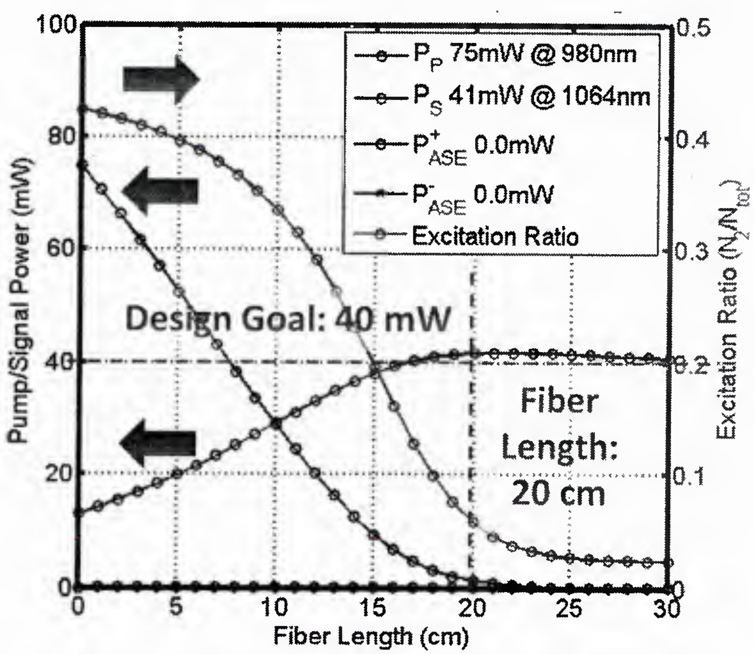
WDM: Wavelength-division multiplexer; ISO: Isolator;
OC: Output coupler; FBG: Fiber Braggs grating

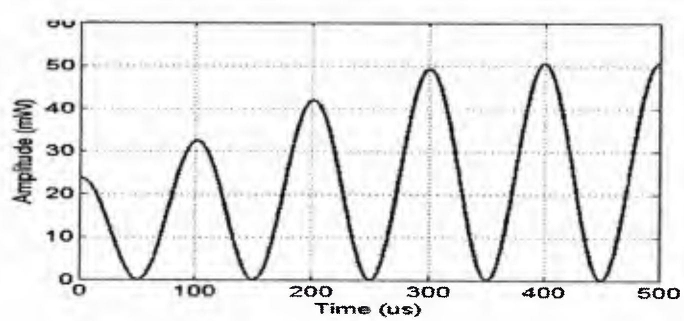


Fiber Amplifier Simulations

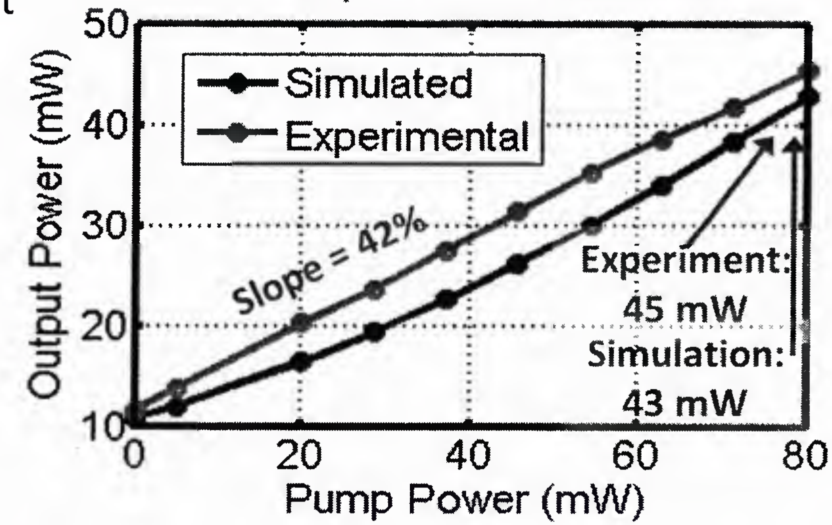
Mathworks.com: "Fiber Lasers and Amplifiers Design Toolbox"

- Numerical modeling of fiber amplifiers using cust to solve rate equations
- Both steady state and dynamic simulations

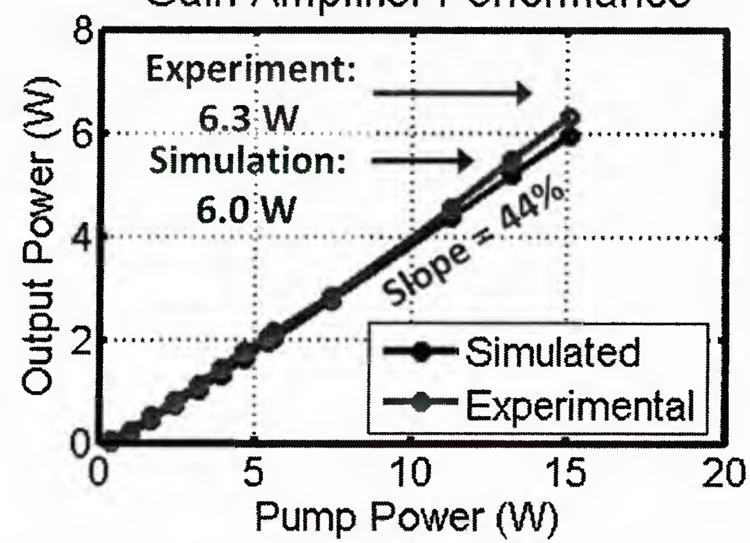




Preamplifier Performance



Gain Amplifier Performance



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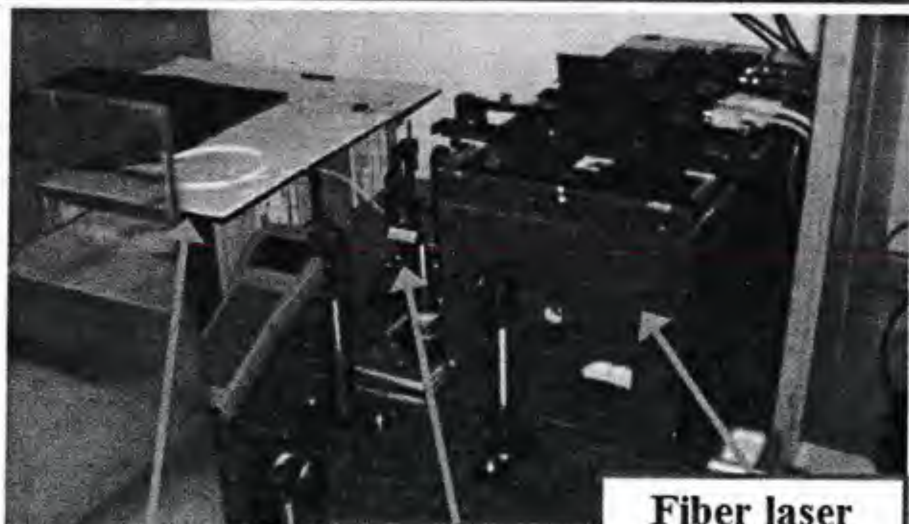
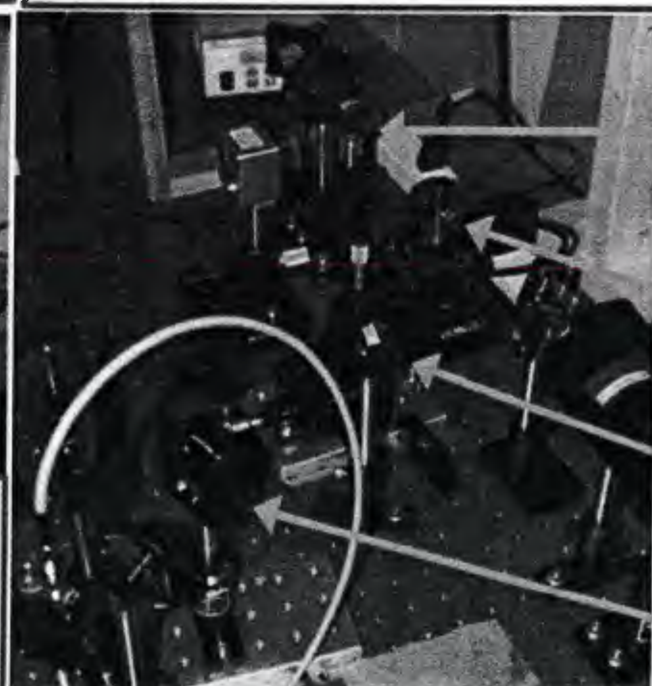
Chaotic Lidar Transmitter

Chaotic Fiber Laser	→	Fiber Amplifiers	→	Frequency Doubler	→	Underwater Channel H(f)
High Frequency		High Power		Green		Channel Identification

Fiber Laser and Amplifier



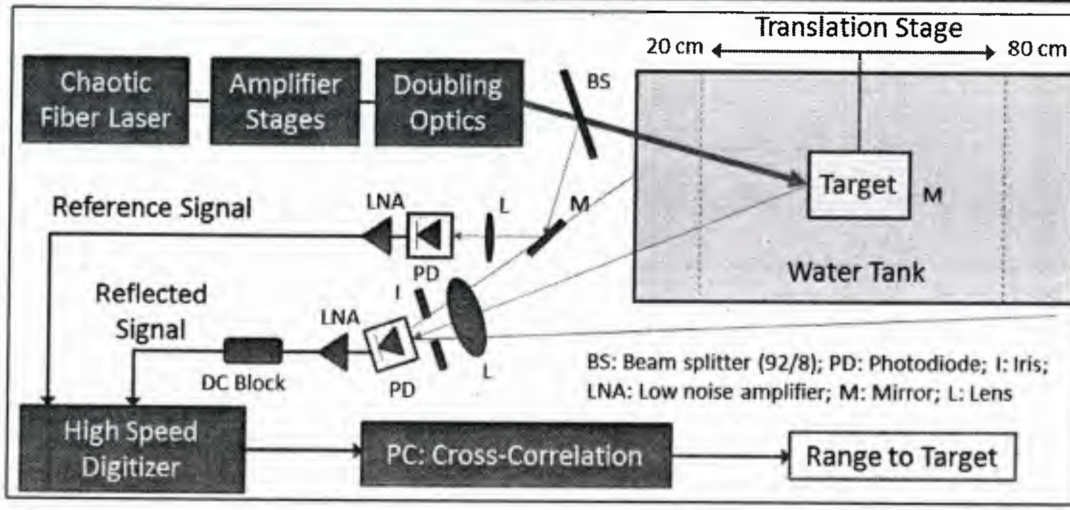
Frequency Doubler

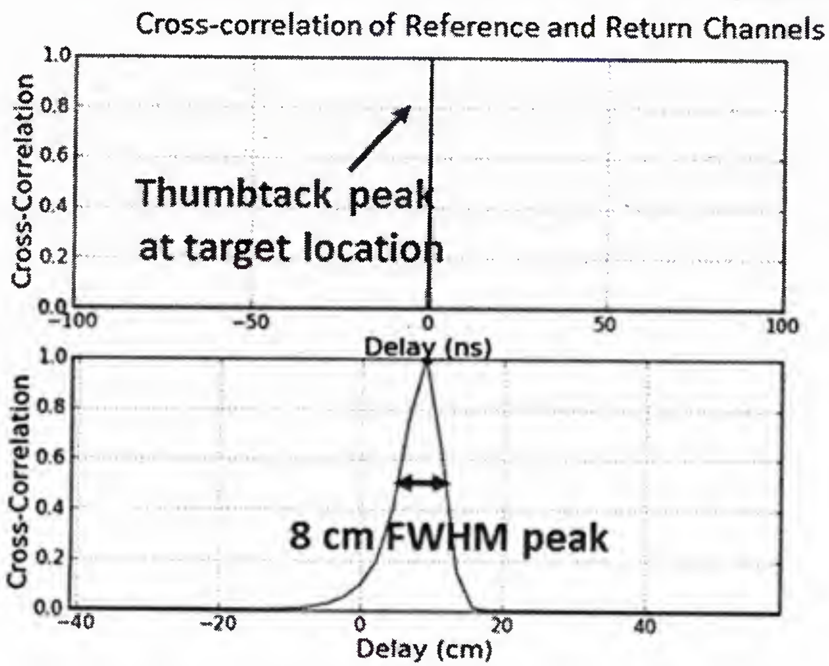


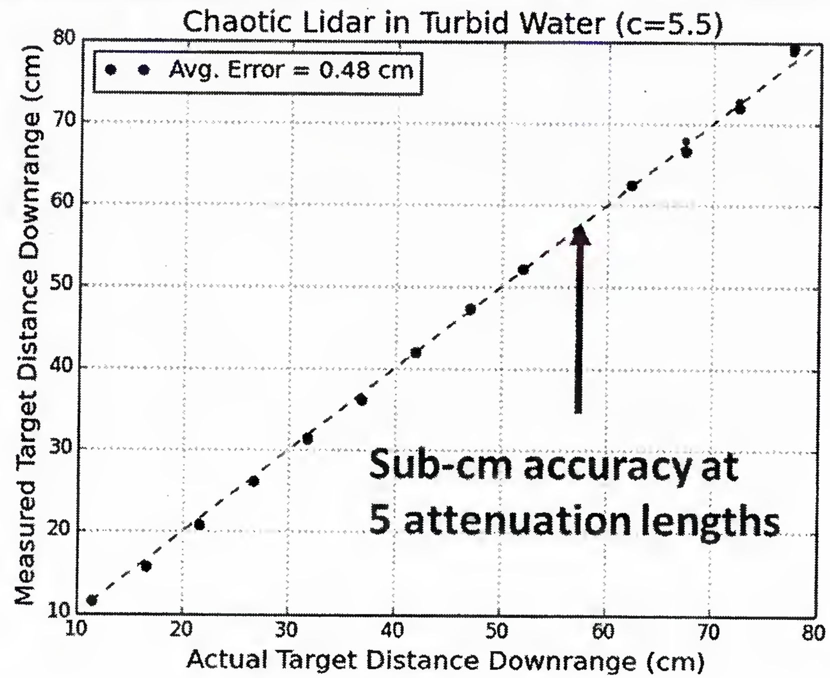
Ranging

Correlation-based ranging:

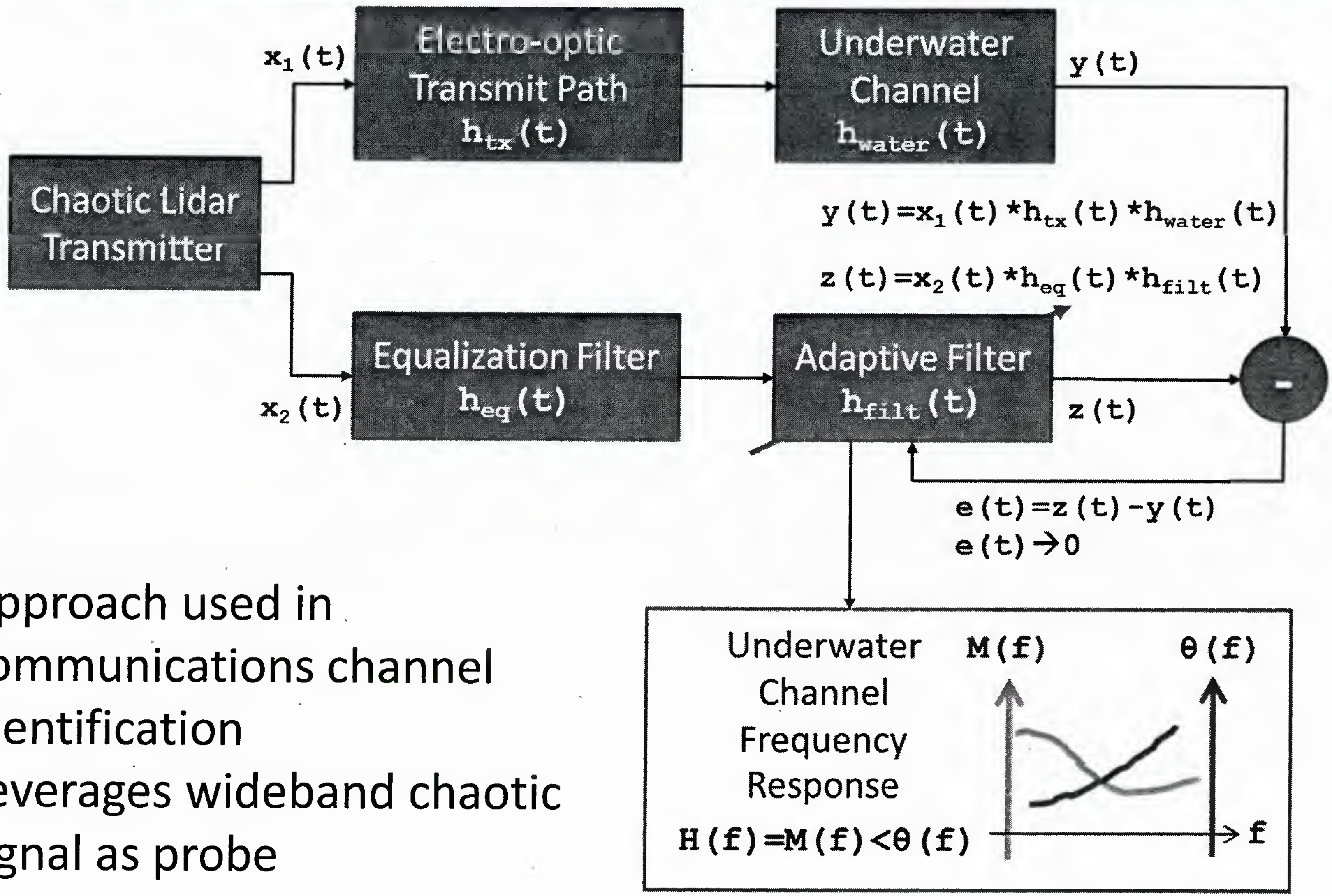
- Wideband → high resolution
- Processing gain → sensitivity
- Unambiguous thumbtack peak







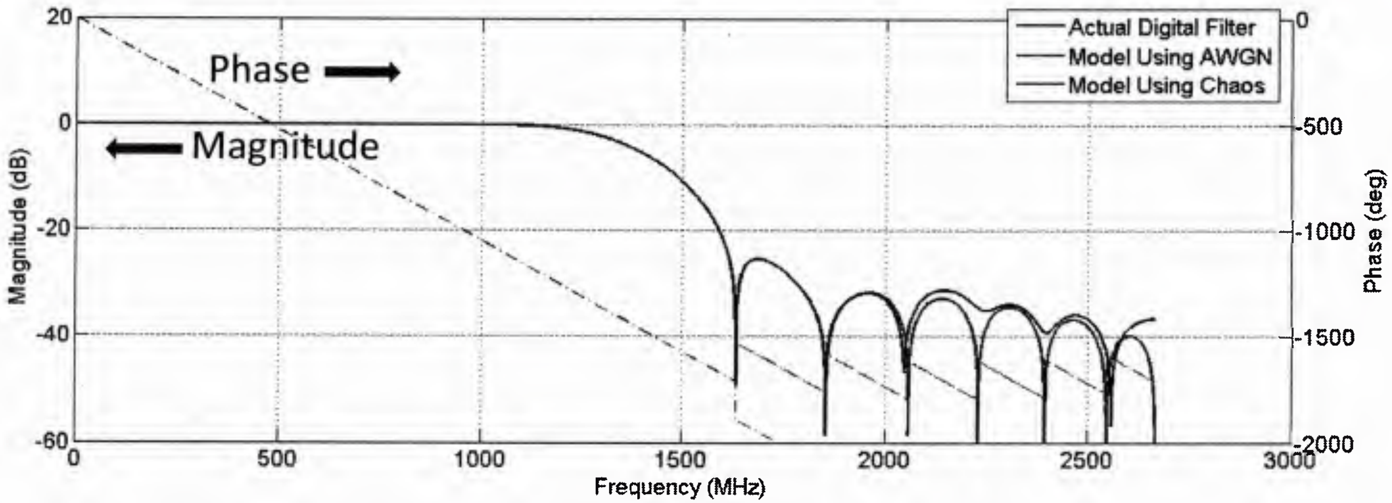
Channel Identification



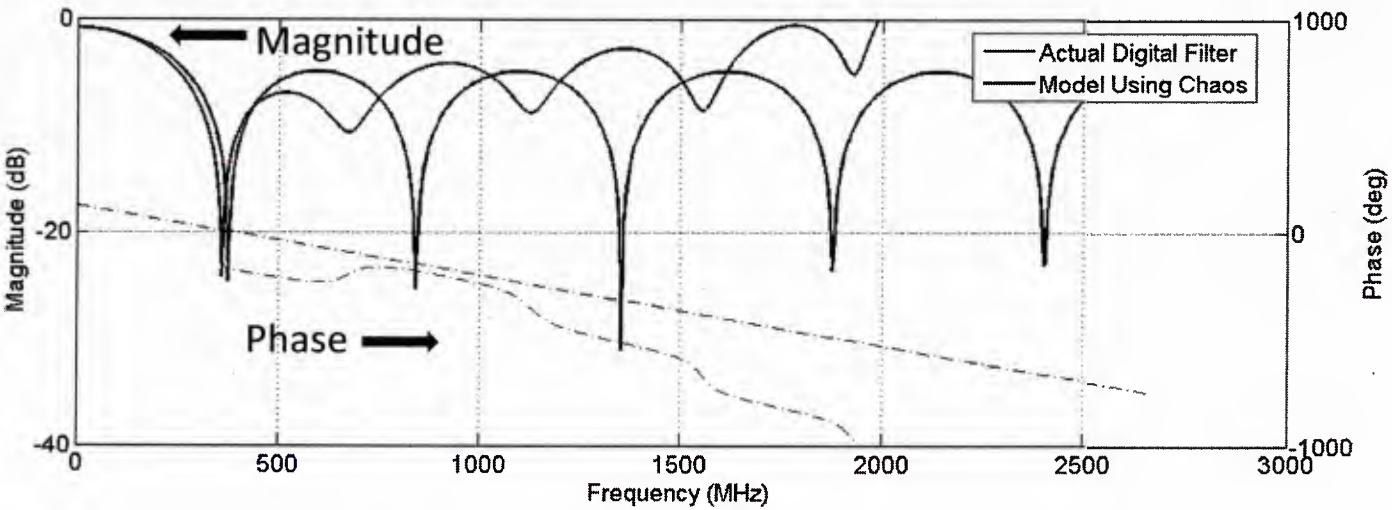
- Approach used in communications channel identification
- Leverages wideband chaotic signal as probe

System Proof of Concept

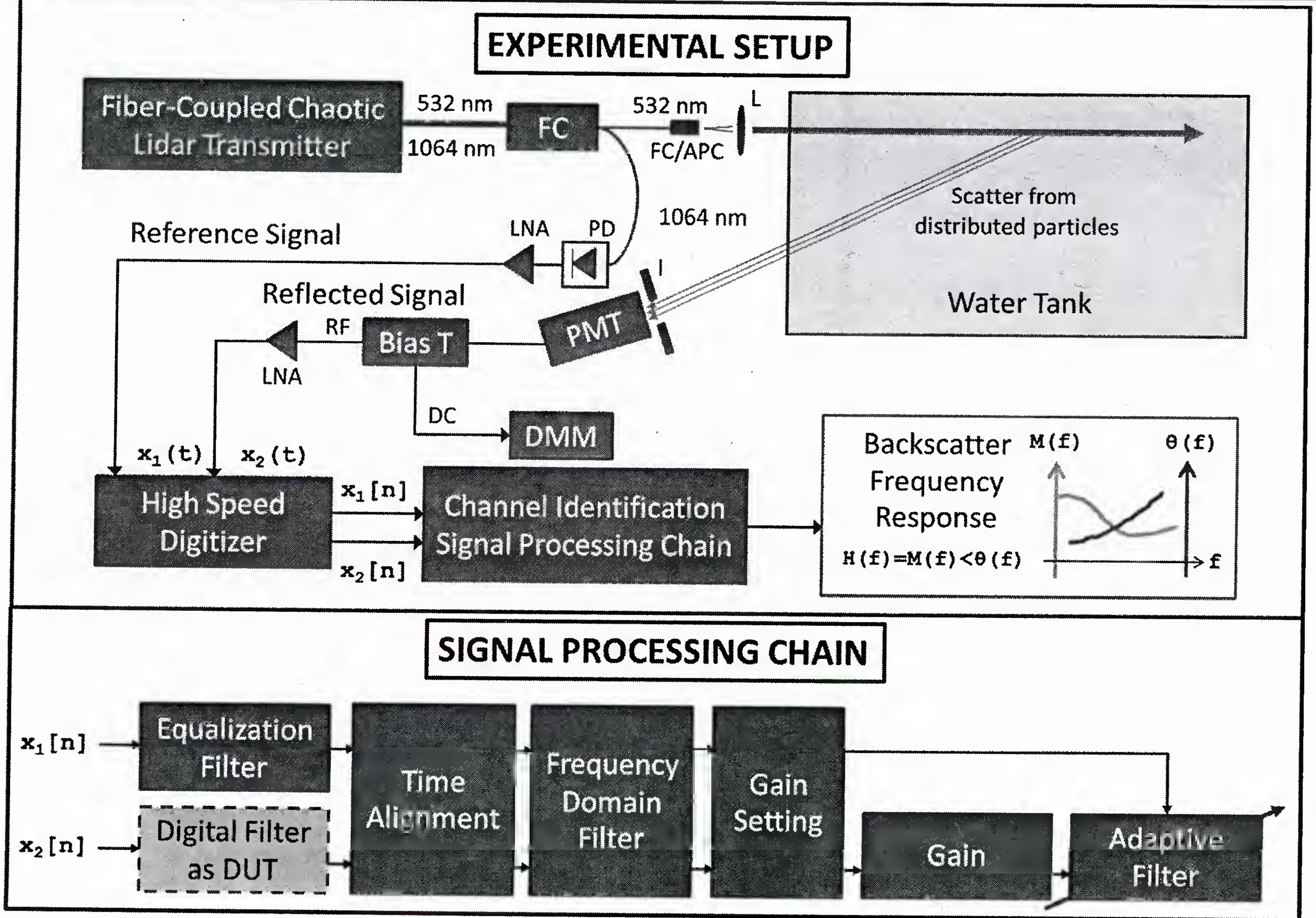
- Digitized chaotic signal used for channel identification on known digital filter



- Free space channel identification using known digital filter as DUT



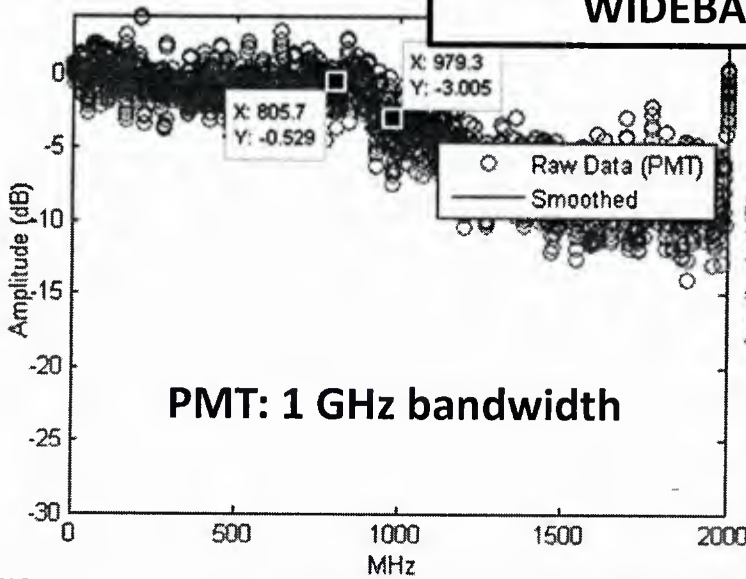
Channel Identification Experimental Setup

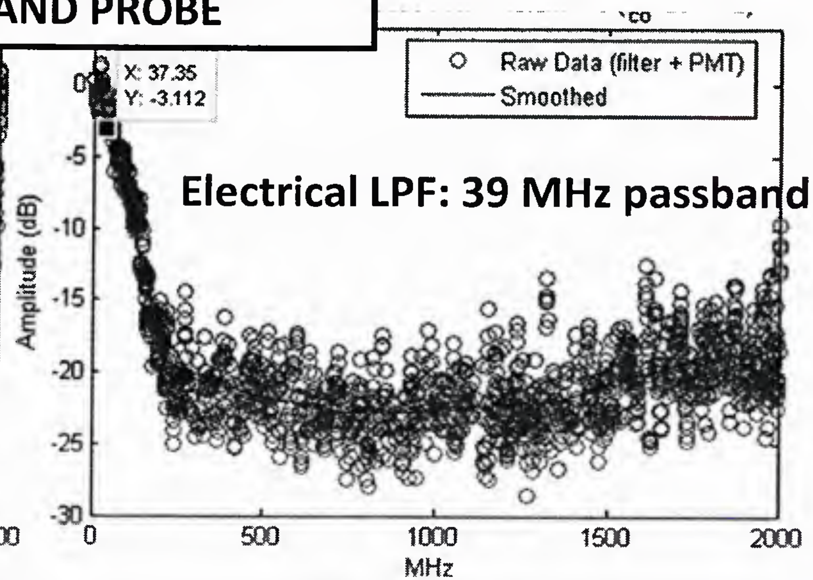


FC: Fiber coupler; L: Lens; PD: Photodiode; M: Mirror; LNA: Low-noise amplifier; PMT: Photomultiplier tube;
RF: Radio frequency; DC: Direct current; DMM: Digital multimeter; DUT: Device under test

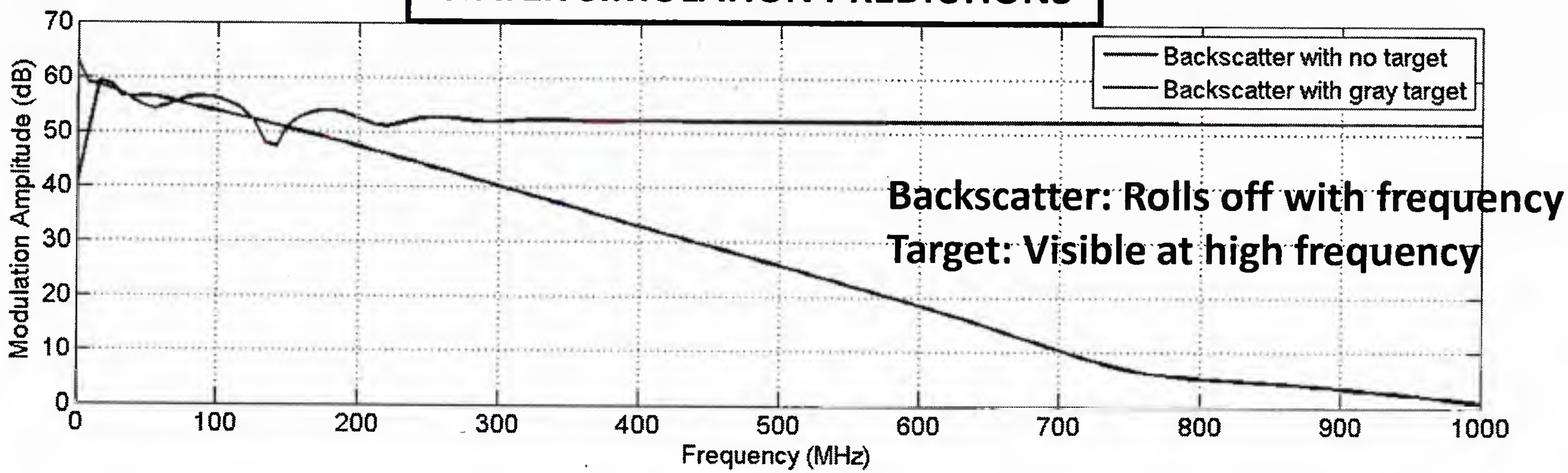
Channel Identification

WIDEBAND PROBE





WATER SIMULATION PREDICTIONS



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Status and Future Work

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- ☑ Design high frequency, scalable power transmitter
- ☑ Adaptive receiver to model channel
- ☑ Characterize electro-optic components
- ☐ Water measurements: Show frequency response of scatter, impact on performance

Conclusion

- New tool for water measurements
  - Motivation for channel identification
  - Internally modulated fiber laser addresses technology challenges for transmitter
  - Adaptive receiver provides usable model of channel